Telecommunication Networks (TCNET, EIE443)

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All materials are available at WebCT3.8.
http://webct2.polyu.edu.hk/welcome/

Syllabus

Overview of Telecommunication Networks and Industry (4 Hrs)

- 1.1 Trends, technologies and network elements in telecommunication networks.

- 1.2 Telecommunication industry in Hong Kong: Regulatory bodies, major telecommunication operators, major telecommunication services and activities.

Syllabus

Queuing Theory and Traffic Engineering (12 Hrs)

- 2.1 Poisson source characteristics/
- 2.2 Analysis of different queuing systems: M/M/1, M/M/2, M/M/N/N queues.
- 2.3 Traffic engineering: Erlang's formula, blocking probability/

Syllabus

- **PCM and Digital Multiplexing Hierarchy**
- **(10 Hrs)**
- 3.1 Telecommunication network hierarchy.
- 3.2 Pulse Coded Modulation (PCM), digital multiplexing hierarchies: T1, E1, T2, and T3 carrier systems.
- 3.3 Plesiochronous and synchronous multiplexing.
- 3.4 SONET and SDH transmission systems.

Syllabus

- **Telecommunication Switching, Routing, and Signaling (10hrs)**
- 4.1 Circuit switching in telecommunication and basic circuit switch design: Time switching and space switching and their various combinations.
- 4.2 Routing in telecommunication networks.
- 4.3 Signaling in telecommunication networks: channel associated signaling, common channel signaling, and Signaling System Number 7 (SS7) signaling.

Assessment

- **Continuous assessment: 40%**
  - Tests   15%
  - Lab Reports   10%
  - Assignments   15%
- *Note:* If a student who fails to submit one component on time or copies other's work, he/she will get zero marks in that component. In addition, some marks will be further deduced from the total marks of the continuous assessment.
- • **Final Examination (2.5 Hours): 60%**

- For students admitted 2001 onwards, they need to pass (D grade or above) both continuous assessment and final examination in order to pass this subject

Acknowledgements

- **Special thanks to Dr. C. K. Leung, Dr. Morris Wang and Dr. K. T. Lo for providing the previous years notes. Part of the teaching materials are based on their work.**

Reference Materials

- T. S. Ramteke, *Networks*, 2nd ed
- Schwartz, M., *Telecommunication Networks: Protocols, Modeling and Analysis*, Addison-Wesley, 1987
- Schwartz, M., *Broadband Integrated Networks*, Prentice-Hall, 1996
- Flood, J.E., *Telecommunications Switching, Traffic and Networks*, Prentice Hall, 1994

Reference Materials (cont'd)

- Kershenbaum, A., *Telecommunications Networking Design Algorithms*, McGraw Hill, 1993
- Saadawi, T.N. and Ammar, M.H., *Fundamentals of Telecommunication Networks*, John Wiley & Sons, 1994

Reference Materials (cont'd)

- Lee, W.S. and Brown, D.C., Advances in Telecommunications Networks, Artech House, 1995
- Stallings, W., *ISDN and Broadband ISDN*, Maxwell and MacMillan, 1992

Reference Materials (cont'd)

- IEEE Communications Magazine (PolyU Serial No.: TK5101.A1 I34)
- IEEE Spectrum Magazine
- TELECOM Asia Ma Magazine

Reference Materials (cont'd)

- ITU-T Recommendations
- ATM-Forum Standards

Overview of Telecommunication Networks and Industry

What is a Network?

- A telecommunication network allows users to be interconnected in a cost-effective way to exchange information
- The network would provide added-value services as well

Network Devices

- A telecommunication network is defined in terms of a set of devices, mechanisms, and procedures
- The devices are usually network switches (nodes), interconnected by transmission links
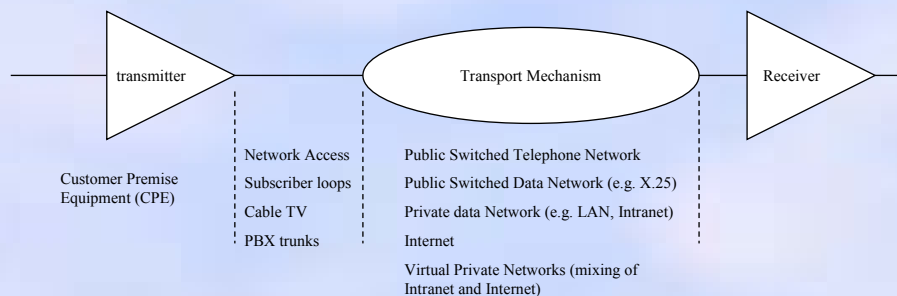
Network Examples

- Well-known examples of telecommunication networks are:
  - The telephone network, which has been in operation for more than 100 years
  - The TELEX network
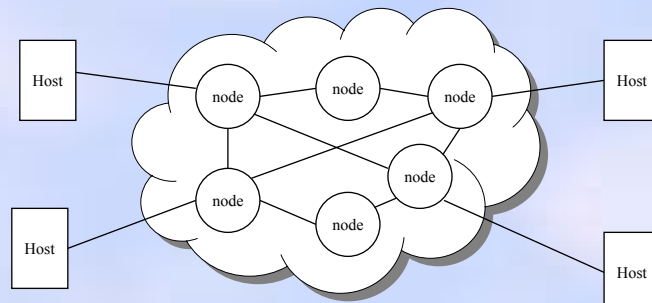 - The mobile network
  - The Internet

Tecommunication Networks

Function	Telegraph Network	Telephone Network	Internet
Basic User Service	Transmission of telegrams	Bi-directional real-time transfer of voice signals	Datagram & reliable stream service between computers
Switching Approach	Message switching	Circuit switching	Connectionless packet-switching
Terminal	Telegraph, Teletype	Telephone, modem	Computer
Information representation	Morse, Baudot, ASCII	Analog voice or PCM digital voice	Any binary information
Transmission system	Digital over various media	Analog and digital over various media	Digital over various media
Addressing	Geographical addresses	Hierarchical numbering plan	Hierarchical address space
Routing	Manual routing	Route selected during call setup	Each packet routed independently
Multiplexing	Character multiplexing, Message multiplexing	Circuit multiplexing	Packet multiplexing, shared media access networks

A Network Model

transmitter — Transport Mechanism → Receiver

Customer Premise Equipment (CPE)

Network Access
Subscriber loops
Cable TV
PBX trunks

Public Switched Telephone Network
Public Switched Data Network (e.g. X.25)
Private data Network (e.g. LAN, Intranet)
Internet
Virtual Private Networks (mixing of Intranet and Internet)

A Network Model (cont'd)

Network Nodes

- The nodes in the network are machines or computers which either provide connections for the users in the case of circuit-switched mode of operation, or relays user data in the case of data communication

- The nodes may be customer nodes, switching nodes, transmission nodes, and service nodes
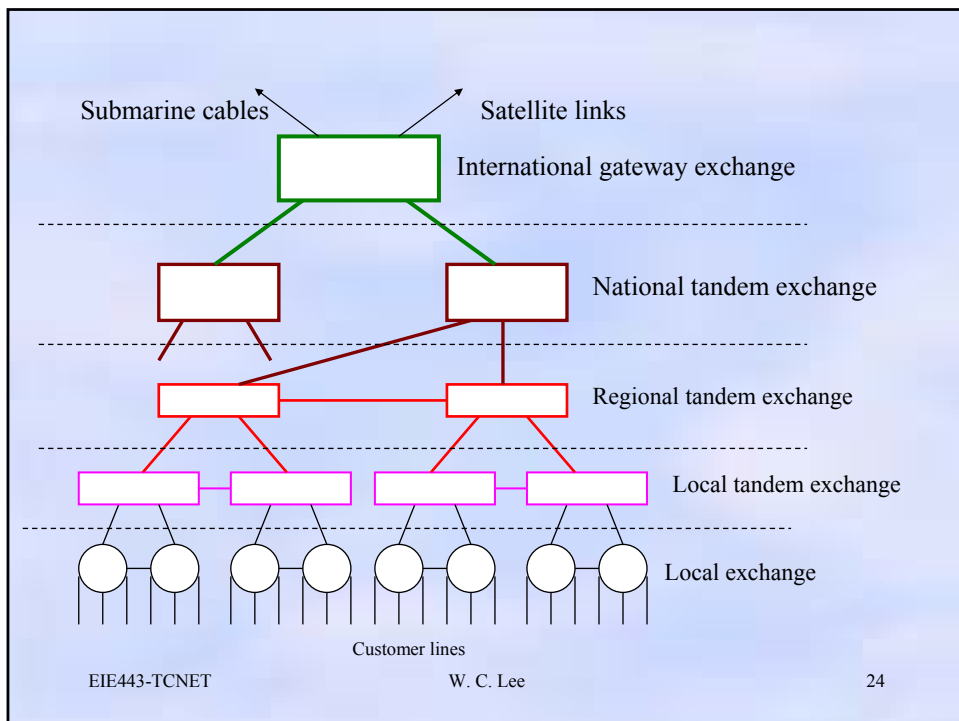
Network Nodes (cont'd)

- nodes can also be classified as:
  - terminals: CRT terminal, PC, workstation,
  - telephone
  - hosts: a large computer, or a large workstation
  - multiplexors/concentrators
  - local switches - allow attached facilities and devices to communicate directly with one another
  - tandem switches - to interconnect nodes
  - gateways: devices which interconnect networks

Network subsystems

- A telecommunication network is a complicated structure, it may be divided into different subsystems:
  - transmission systems
  - switching systems
  - signaling systems

A hierarchical network

- It is usually not economical to have a "large" telecommunication network to serve all users and all areas
- The areas are divided into different hierarchies (or different levels), to provide a cost-effective solution

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Submarine cables   Satellite links

International gateway exchange

National tandem exchange

Regional tandem exchange

Local tandem exchange

Local exchange

Customer lines

Network functions

- To set up a path for electrical signals
- To convert information to/from electrical signals
- To overcome deficiencies (distortion and noise) in the electrical signal path

Network Functions (cont'd)

- Switching - to interconnect channels
- Routing – to select the best path to guide the data from source to destination
- Flow control – to regulate traffic flow rate
- Speed and code conversion
- Security - to prevent unauthorized access
- Backup - to be able to react to failures
- Failure monitoring - to keep track of which components are working and which are not

Network Functions (cont'd)

- Traffic monitoring - to keep track of traffic level
- Accounting - to keep track of who uses the network, for billing purposes
- Internetworking - to provide communication with and across other networks
- Network management - to manage the resources of the network

Networks classification

- Networks may be classified according to the way transmitted signals are transmitted and received:
  - Broadcast networks
  - Switched networks
  - Hybrid networks

Broadcast Networks

- Signals transmitted by one end-user's equipment are automatically heard by all other end-users' equipment

Every station can hear the transmitted signal

| Transmit |

Cable
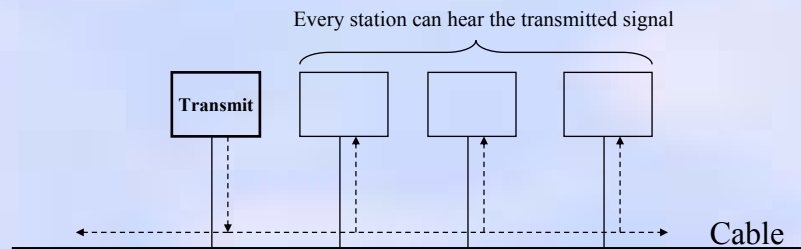
Switched Networks

- Signals have to be routed through network nodes to their desired destination

Host — node — node — node — Host

node

Host — node — node — Host
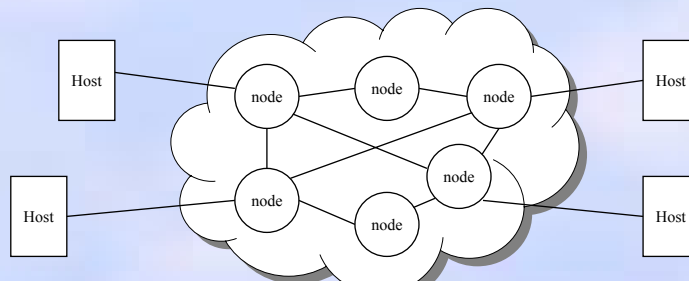
Switched Networks (cont'd)

- Network nodes may have different names, such as:
  - Data Circuit-terminating Equipment (DCE, due to ITU-T)
  - Interface Message Processor (IMP, due to ARPANET)
  - Switch (for telephone network)
  - Router (for Internet

Switched Networks (cont'd)

- The user equipment is usually called the Data Terminal Equipment (DTE, due to ITU-T), which may be:
  - a telephone set
  - a terminal
  - a large host computer
  - a personal computer
  - a workstation

Hybrid Networks

- This type of networks have a mix of broadcast and switched networks
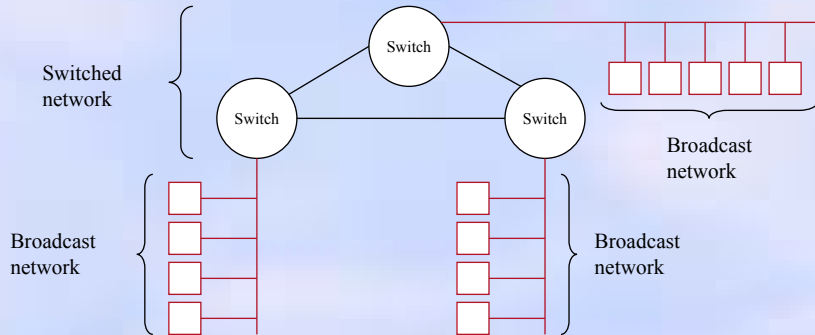
Geographic Classification

- a network may also be classified according to its geographic extent:
  - local area networks (LAN) - restricted to several km, a single office or a factory floor
  - metropolitan area networks (MAN) - 10's of km, a campus
  - wide area networks (WAN) - 100 or 1000 of km, international scale

Range and Data Rate
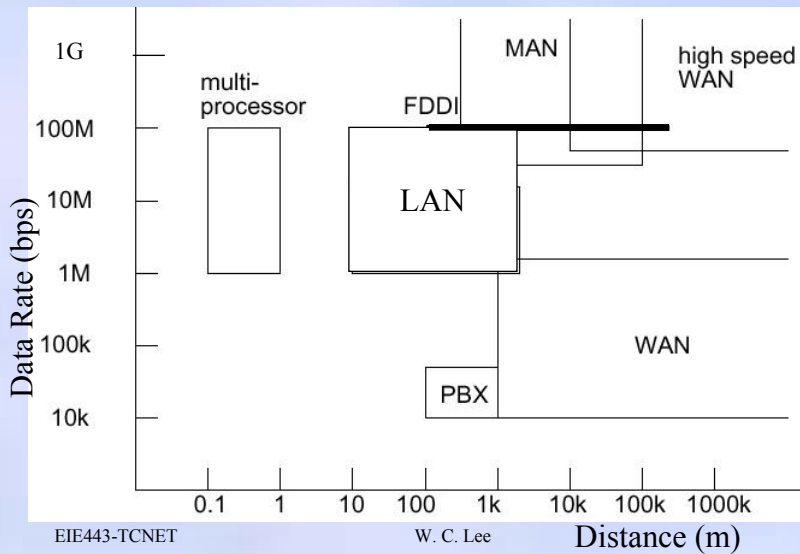
Other Classifications

- Centralized *vs*. distributed (control regime)
- Private *vs*. public (ownership)
- Voice, data and video (information type)
- Analog, digital, radio, satellite (transmission technique)

Other Classifications (cont'd)

- Broadband or narrowband (data rate and speed of response)
- Single media (e.g. telephone) or multimedia (e.g. broadband ISDN)

Other Classifications (cont'd)

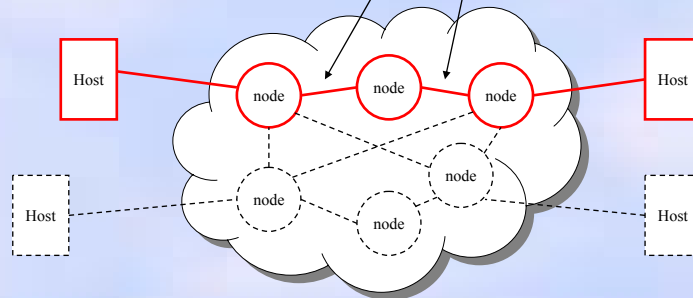- Mesh (fully-connected), bus, ring, star, tree (topology)

Mesh   Bus   Ring   Star
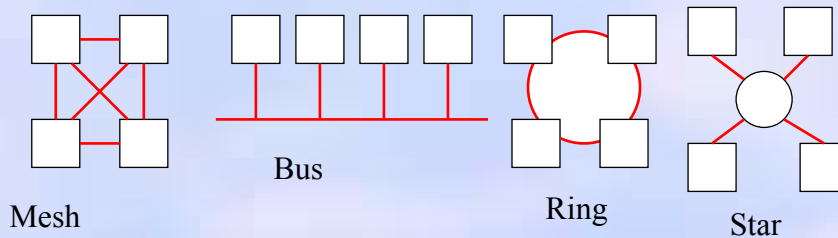
Switching Techniques

Four Types

- Circuit switching
- Message switching
- Packet switching
- Cell switching

Circuit Switching

- An illustration:

A circuit is set up for communication

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Circuit-switching (cont'd)

- This is the oldest form of switching, dates back to the telegraph era, the most common method in telephone switching
- A dedicated path - a connected sequence of links - between the calling and the called stations is set up for the duration of the call
- The quality of the dedicated path is guaranteed during the connection life-time

Circuit-switching (cont'd)

- Network use is initiated by a connection phase, during which a circuit is set up between source and destination, and terminated by a disconnect phase
- Signal or data is transmitted progressively over all the links in the circuit with no intermediate store-and-forward delays
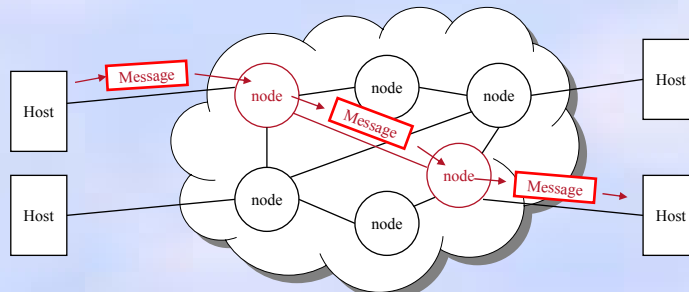- The delay for setting up a circuit can be high

Circuit-switching (cont'd)

- Events in circuit switching
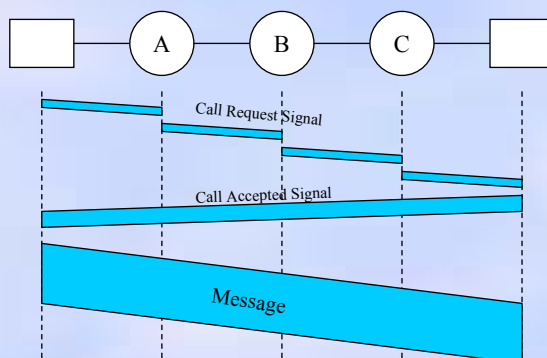
Message Switching

- A message is sent from one node to the next node, stored, and then sent to the further next node until the destination is reached

Message Switching (cont'd)

- There is no need to establish a continuous path in order for the sender to communicate with the receiver
- This mode of operation is also called "store-and-forward"
- Since messages can vary in sizes, the overall delay will vary widely
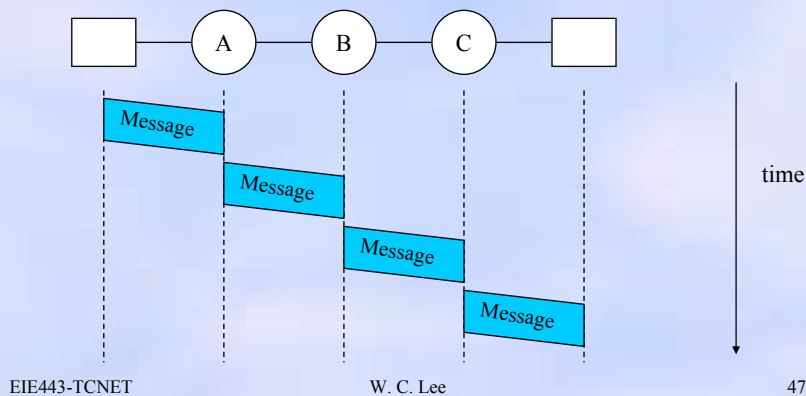- Example: telegram, telex

Message Switching (cont'd)

- Events in message switching

Packet Switching

- A long message is divided into a series of smaller units called "packets" – of limited lengths
- These packets traverse the network until they reach the destination node
- The received packets are then reassembled into the original message
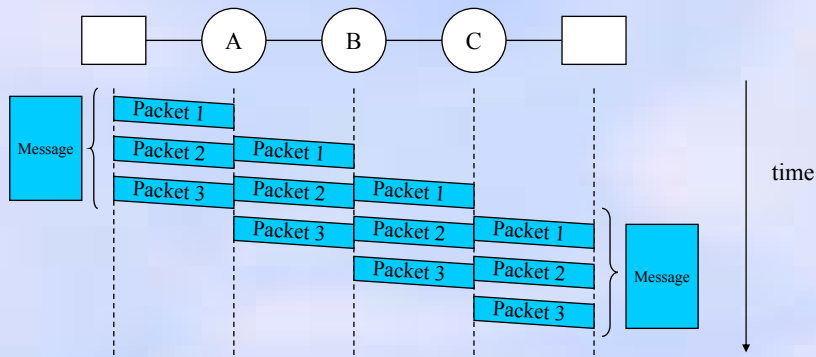
Packet Switching (cont'd)

- Pipelining: many packets of the same message may be transmitted within the network simultaneously, thus reducing overall delay in transmitting the message

Packet Switching (cont'd)

- Two modes of packet switching are possible:
  - virtual circuit mode is such as packets will always traverse the same set of links for a source-destination pair throughout the connection
  - datagram mode is such that each packet is transported independent of others

Packet Switching (cont'd)

- Events in packet switching

Cell Switching

- Cell switching is similar to packet switching, but the information unit to be switched is a cell, which is a small and fixed-size packet, (e.g. 53 bytes for Asynchronous Transfer Mode (ATM) network)

- With fixed-size small packets, the support of different traffic with different characteristics (e.g. multimedia traffic) can be efficient (with the achievement of multiplexing gain)
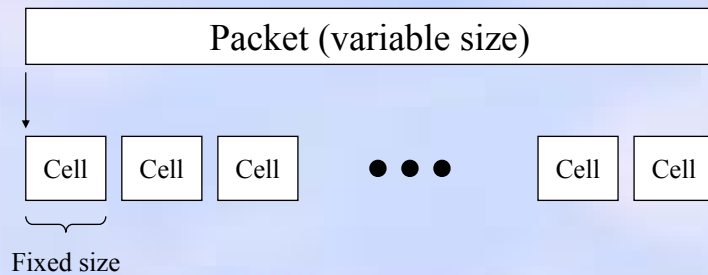
Cell Switching (cont'd)

• Segmentation and reassembly

Packet (variable size)

Cell	Cell	Cell	• • •	Cell	Cell

Fixed size

Access Methods

• An access control method is needed to coordinate the use of a shared transmission medium (e.g. a bus)

• Access methods can be categorized as:
   – Random access control
   – Distributed access control
   – Centralized access control

Random Access Control

- A station is allowed to transmit data whenever it finds the medium is free
- A method is required to resolve <u>contention</u>, to recover from <u>collision</u>, or to avoid collision:
  - CSMA/CD, CSMA/CA
  - Slotted ring
  - Register Insertion

Distributed Access Control

- All stations <u>cooperate</u> to share the use of the medium
- For example, in <u>token passing</u>, a station is allowed to transmit only if it possesses a special bit pattern called "token"

Centralized Control

- Access is controlled by a <u>central master</u>
- Methods include:
  - Polling – a master station asks the slave stations in turn if they have anything to send
  - Circuit switching (Telephone, PABX)
  - Time-division multiple access (TDMA)

Network Services

- Network services are something provided to the users by network
- Example: Plain Old Telephone Services (POTS):
  - You dial your friend's telephone number and then the telephone company provides a connected path from your telephone to your friend's, until you (or your friend) hangs up
  - Other services: call waiting, conference call, morning call, call forwarding, caller number display ...etc
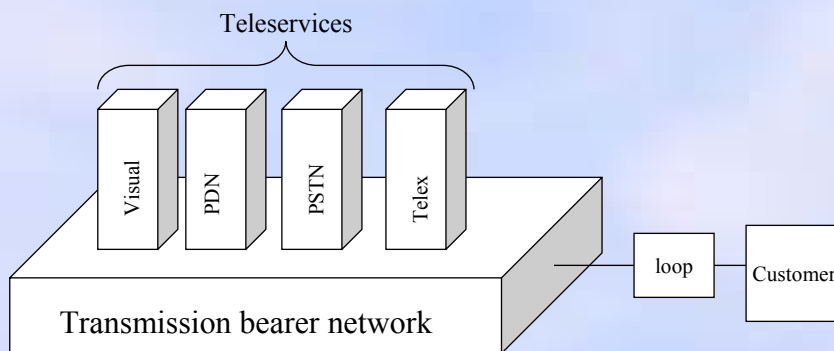
Network Services (cont'd)

- different applications require different services, and hence different networks, such as:
  - the public switched telephone network (PSTN)
  - the public switched telegraph network (Telex)
  - private networks for voice and data (using dedicated lines leased from the telephone company)
  - cellular radio networks (mobile communications)
  - public data networks (PDN)

Network Services (cont'd)

- Telecommunication network services can be broadly divided into two groups:
  - Teleservices - depends on particular terminal apparatus
  - Bearer services - transmission capacity
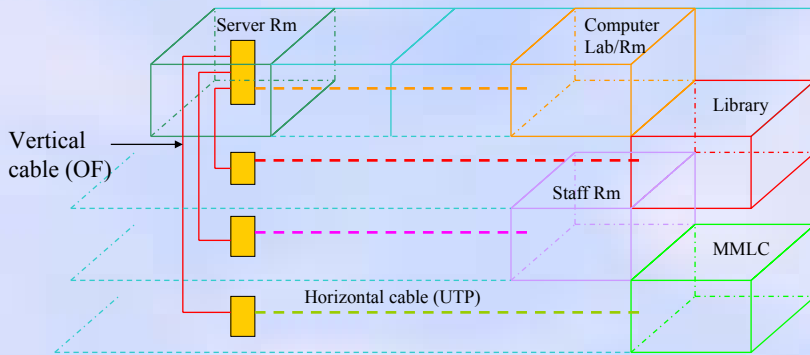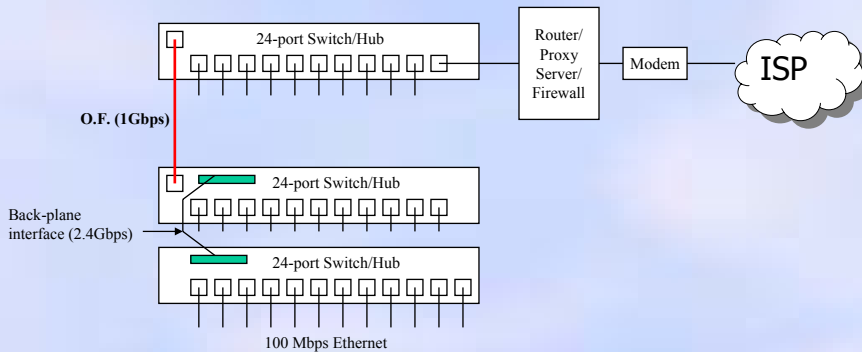
Network Services (cont'd)

- An illustration:

Teleservices

Transmission bearer network

Visual | PDN | PSTN | Telex

loop | Customer

Case Study 1

School LANs in Hong Kong

Basic School LAN Structure

Server Rm

Computer
Lab/Rm

Library

Vertical
cable (OF)

Staff Rm

MMLC

Horizontal cable (UTP)

Physical Map

- Physical Map – an example:

24-port Switch/Hub

Router/
Proxy
Server/
Firewall

Modem

ISP

O.F. (1Gbps)

24-port Switch/Hub

Back-plane
interface (2.4Gbps)

24-port Switch/Hub

100 Mbps Ethernet
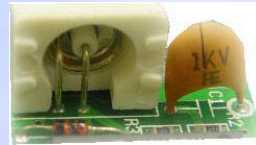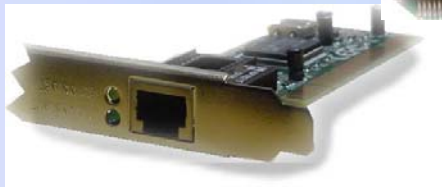
Logical Diagram
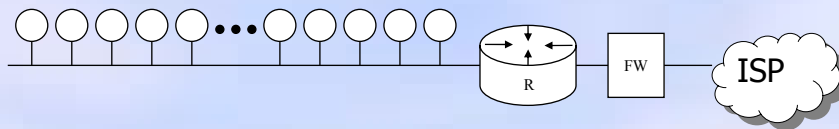
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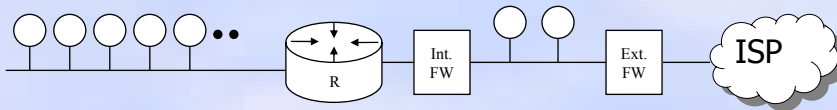
LAN Equipments

Network Interface Card

- NIC – Provides networking capability to a PC

Structured Cabling System

- Conforming to TIA568A/B standard
- Work area, patch cords, wall plates, horizontal wiring, wiring closets, telecommunication room(s), rack-mountable patch panels, vertical wiring, Optical Fiber cables

Structured Cabling System
(cont'd)

19-inch rack

Horizontal cable

Patch panel

Inter-switch stack cable

Switch

Patch cords (multi-stranded)

Vertical cable
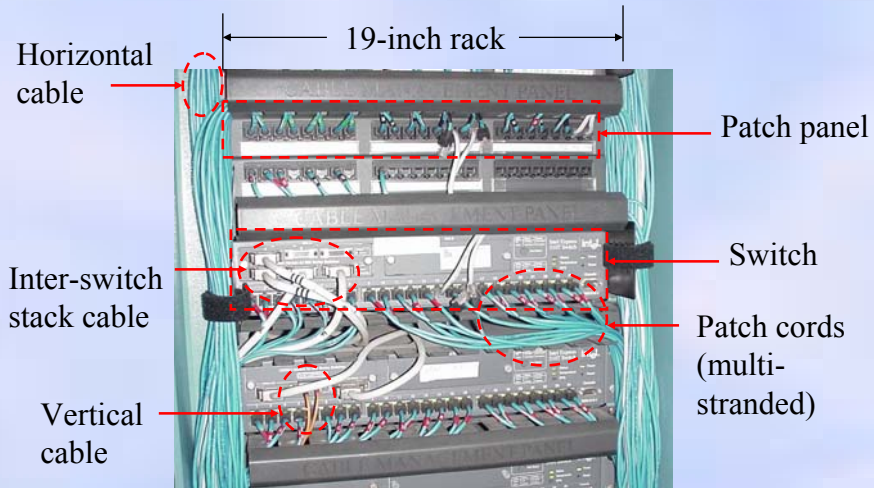
Structured Cabling System (cont'd)

• Patch Panel

Structured Cabling System (cont'd)

• RJ45 plugs

Structured Cabling System (cont'd)

• RJ45 Jack and wall plate:

Structured Cabling System (cont'd)

- UTP cables

Patch cord

Horizontal wire
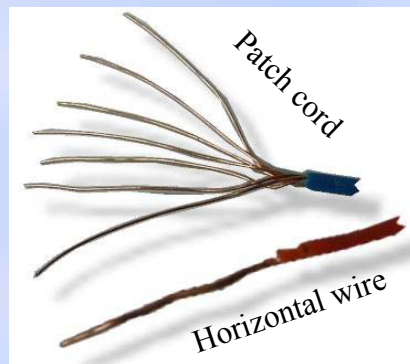
Repeaters and Hubs

- Repeaters – extending LAN range
- Hubs – multi-port repeaters

Repeaters and Hubs (cont'd)

- 3Com Hub

Bridges and Switches

- Bridges and Switches – traffic isolation
- Cisco Switch back panel:

Bridges and Switches (cont'd)

- Cisco switch (dismantled):

Bridges and Switches (cont'd)

- Cisco Switch in operation:

Bridges and Switches (cont'd)

• Intel Switch:

Router

• Direct data to/from the Internet

Modem

- A modem carries digital data over a long distance (e.g. from school to ISP)

Proxy Server

- A proxy server caches information from the Internet – improves efficiency

Firewall

- A firewall guards against malicious traffic from the Internet

Case Study 2

Telecommunications in Hong Kong

Telecommunication Indicators

- 100% digital main lines since 1993
- Main telephone lines in operation:
  - 3.926 Million
- Cellular mobile telephone subscribers:
  - 5.447 Million
- Cellular subscribers per 100 inhabitants
  - 81.16%

Telecommunication Indicators
(cont'd)

- International Telephone Traffic
  - International outgoing: 3.142 billion minutes
  - International incoming: 1.883 billion minutes
- Staff
  - Full-time telecommunications staff: 38,625
- Monthly rental charge for residential telephone service
  - HK$110

Telecommunication Ordinance

- Hong Kong Law Chapter 106
- No person shall establish or maintain any means of telecommunication…
- No person shall possess or use any apparatus for radiocommunication…
- Unless he/she has a licence granted by the governor-in-council or by the <u>Telecommunications Authority</u>

Penalty

- On summary conviction, a fine of <u>HK$50000</u> and to imprisonment for <u>2 years</u>
- On conviction on indictment, to a fine of <u>HK$100000</u> and to imprisonment for <u>5 years</u>

Telecommunications Authority

- Section 5: the governor may appoint such public officer as he thinks fit to be the Telecommunications Authority (TA)
- The TA is the head of the office of the telecommunications authority (OFTA), and is also Director-General of telecommunications
- Current TA is Mr. Anthony S.K. Wong

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│      Telecommunication        │
│         Ordinance             │
└──────────────┬───────────────┘
               │
               ▼
┌──────────────────────────────┐
│   Governor (Chief Executive)  │
└──────────────┬───────────────┘
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│  Telecommunications Authority │
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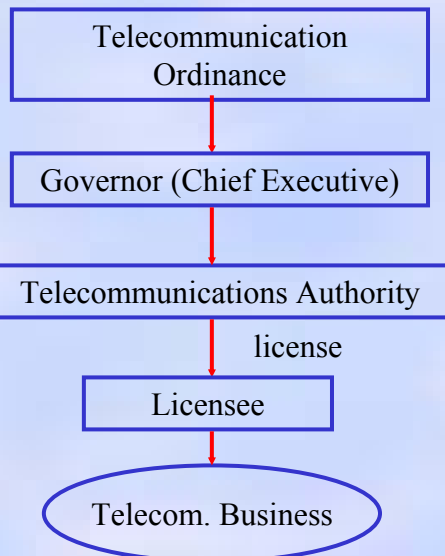
Types of License

- Fixed Telecommunication Network Services (FTNS) license
- Public Mobile Radiotelephone Service (PMRS) Operators Public Radiocommunication Service (PRS) license
- Personal Communication Services (PCS) Operators Public Radiocommunication Service (PRS) license

Types of License (cont'd)

- Internet Service Providers (ISP) Public Non-Exclusive Telecommunication Service (PNETS) license
- External Telecommunication Service Operators Public Non-Exclusive Telecommunication Service (PNETS) license

Types of License (cont'd)

- Public Radiopaging Service Operators
  Public Radiocommunication Service (PRS)
  license

FTNS Licensees

- PCCW-HKT Telephone Limited
- Hutchison Global Crossing Limited
- Wharf New T & T Limited
- New World Telephone Limited

Mobile Carrier Licensees

- Hong Kong CSL Limited
- Hutchison 3G HK Limited
- SmarTone 3G Limited
- SUNDAY 3G (Hong Kong) Limited

PMRS Operators

- "PMRS" stands for Public Mobile Radiotelephone Service
- Hong Kong CSL Limited
- Hutchison Telephone Company Limited
- Hutchison Telephone Company Limited
- SmarTone Mobile Communications Limited
- Hong Kong CSL Limited

PCS Licensees

- "PCS" stands for Personal Communications Service
- Peoples Telephone Company Limited
- New World PCS Limited
- Hutchison Telephone Company Limited
- SmarTone Mobile Communications Limited
- Hong Kong CSL Limited
- Mandarin Communications Limited (SUNDAY)

ISP licensees

- PCCW-HKT Network Services Limited
- PCCW IMS Ltd.
- BT (Hong Kong) Ltd.
- IBM China/Hong Kong Corporation
- WOL Communications Ltd.
- Global One Communications, Ltd.
- …others (total 256)

Telecommunications Services

- Local Fixed Telecommunications Network Services (FTNS)
- International Telecommunications Services
  - Telephone, facsimile, data, TV, telex, telegram, private leased circuits

Telecommunications Services
(cont'd)

- Satellite
  - 41 earth station antennas
  - Cable & Wireless HKT
  - Asia Satellite Telecommunications Co. Ltd.
  - APT Satellite Co. Ltd.
  - Hutchvision Hong Kong Ltd.
  - Galaxy Satellite Broadcasting Ltd.

Telecommunications Services
(cont'd)

- Submarine Cable
  - Okinawa-Luzon-Hong Kong: linking HK, Phillippines, Japan, North America
  - Singapore-Hong Kong-Taiwan: linking HK, ASEAN countries, Australia, Europe
  - Hong Kong-Japan-Korea (H-J-K): optical fibre, linking Hong Kong, Japan, Korea, North American

Telecommunications Services
(cont'd)

  - Asia Pacific Cable Network (APCN): linking HK, Taiwan, Korea, Taiwan, Thailand, Phillippines, Malaysia, Singapore, Indonesia, Australia
  - Fibre-optic Around the Globe: linking Hong Kong, Thailand, Shanghai, South Korea, and Japan